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L4	L3 and micelles	11	L4
L3	vip same asthma	78	L3
L2	(vip or glucagon or secretin) and micelles	196	L2
L1	(vip or glucagon or secretin) same micelles	7	L1

END OF SEARCH HISTORY

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L2: Entry 123 of 196

File: USPT

Jun 23, 1998

DOCUMENT-IDENTIFIER: US 5770570 A

TITLE: Method of delivering a vasoactive intestinal polypeptide, an encapsulated vasoactive intestinal polypeptide, and a method of making the encapsulated vasoactive intestinal polypeptide

Abstract Text (1):

Provided is a method for delivering a vasoactive intestinal polypeptide (VIP) liposome product to a target tissue of a mammal. The VIP is expressed on and in a liposome. Also provided is a method of preparing the VIP liposome product comprising cholesterol, phosphatidyl choline, and phosphatidyl glycerol.

Brief Summary Text (3):

The invention relates to a method of delivering a vasoactive intestinal polypeptide (hereinafter "VIP") to a target tissue, a VIP liposome product where VIP is expressed on and in liposomes, and a method of making the VIP liposome product having increased biological potency and decreased side effects.

Brief Summary Text (5):

VIP is a 28-amino acid neuropeptide which is known to display a broad profile of biological actions and to activate multiple signal transducing pathways. See, Said, S. I. (1984) Peptides 5, (Suppl. 1) 149-150, and Paul, S. and Ebadi, M. (1993) Neurochem. Int. 23, 197-214.

Brief Summary Text (6):

A Schiffer-Edmundson projection of VIP as a π -helix reveals segregation of apolar and polar residues onto the opposite faces of the helix and that this amphipathic character is also evident when VIP is modeled as a distorted α -helix, which is reported in Musso, G. F., Patthi, S., Ryskamp, T. C., Provow, S., Kaiser, E. T. and Velicelebi, G. (1988) Biochemistry 27, 8174-8181. A correlation between the helix-forming tendency of VIP analogues and their biological activity is described in Bodanszky, M., Bodanszky, A., Klausner, Y. S. and Said, S. I., (1974) Bioorganic Chem. 3, 133-140. In pure water, the spectral characteristics of VIP are consistent with those of a random coil. However, organic solvents and anionic lipids induce helix-information in the molecule. See, Robinson, R. M., Dlakney, Jr., E. W. and Mattice, W. L. (1982) Biopolymers 21, 1217-1228; Hamed, M. M., Robinson, R. M. and Mattice, W. L. (1983) Biopolymers 22, 1003-1021; and Bodanszky, M. Bodanszky, A., Klausner, Y. S. and said, S. I. (1974) Bioorganic Chem. 3, 133-140.

Brief Summary Text (9):

VIP belongs to a family of homologous peptides, other members of which are peptide histine isoleucine (PHI), peptide histidine methionine (PHM), growth hormone releasing factor (GRF), pituitary adenylate cyclase activating peptide (PACAP), secretin and glucagon. The sequences of the family of homologous peptides follow (see SEQ ID NOS: 2-11, respectively). Indentities with the VIP sequence are shown by underlining as are the conserved basic residues.

Brief Summary Text (10):

Like VIP, these peptides could form amphipathic helices capable of binding lipids bilayers. In the present invention, VIP was used as the model peptide to show that the biological potency of this family of peptides is increased by expression in and on lipid bilayers.

Brief Summary Text (11):

The biological action of VIP and GRF are believed to be mediated by protein receptors expressed on the cell-surface and intracellular receptors. We have shown that the calmodulin is the likely intracellular receptor for VIP. See Paul et al., "Vasoactive Intestinal Peptide: Its Interactions with Calmodulin and Catalytic Antibodies", *Neurochem. Int.*, Vol. 23, No. 3, pp. 197-214 ; Stallwood et al. "Identity of a membrane-bound vaso active intestinal peptide binding protein with calmodulin.", *J. Biol. Chem.*, Vol. 267, (1992), pp. 19617-19621; Stallwood et al. "Is calmodulin a neuropeptide receptor?" *FASEB J.*, Vol. 7, (1993), p. 1054 (abstr.) , the contents of these documents are expressly incorporated herein by reference. We speculated that intracellular delivery of VIP alone or VIP-calmodulin mixtures bypasses the requirement for cell-surface binding of the peptide and thus enhances the biological actions of the peptide. Provision of the peptides expressed in and on liposomes would achieve intracellular delivery, since the lipid bilayers of liposomes are known to fuse with the plasma membrane of cells and deliver their contents into the intracellular compartment.

Brief Summary Text (12):

A major factor limiting the therapeutic use of VIP has been its reduced bioavailability at target tissues because of proteolytic degradation and a multiplicity of conformations adopted by this peptide.

Brief Summary Text (14):

An objective of the invention is to provide a method of delivering to target tissues peptides belonging to the VIP-GRF family a vasoactive intestinal polypeptide (hereinafter "VIP") which overcomes the problems of conventional methods.

Brief Summary Text (15):

Another objective of the invention is to improve the efficacy and duration of VIP.

Brief Summary Text (16):

The invention relates to a method of delivering VIP to the surface and intracellular compartment of a target tissue of a mammal comprising the steps of forming a VIP liposome product where VIP is expressed on and in the liposome and administering an biologically effective amount of the VIP Liposome product to the target tissue.

Brief Summary Text (17):

Another embodiment of the invention relates to a VIP liposome product composed of cholesterol, phosphatidyl choline, and phosphatidyl glycerol.

Brief Summary Text (18):

A further embodiment of the invention relates to a method of making a VIP liposome product having increased biological potency and decreased side effects comprising the steps of forming the VIP liposome product under conditions where the resultant liposome product has VIP expressed on and in the liposome which comprises cholesterol, phosphatidyl choline, and phosphatidyl glycerol. "[e]xpressed on or in the liposome" is intended to mean the following. "On" connotes that VIP is exposed to the outside solvent and immobilized on the outside surface by insertion into the hydrophobic core of the lipid bilayer as explained in example 2 below.

Brief Summary Text (19):

"In" connotes soluble VIP in the luminal space of the liposomes and on the intraluminal face of the lipid bilayer of the liposomes. All forms of VIP in this liposome construct are likely to be in the helical conformation due to complexation with lipid molecules. Other objects, features, and characteristics of the invention will become apparent upon consideration of the following description and the appended claims.

Brief Summary Paragraph Table (1):

	<u>VIP</u>
HSDAVFTDNYTRLRKQMAVKKYLNSILN rat GRF	HDAIFTSSYRRILGQLYARKLLHEIMNRQQGERNQERSRFN
human GRF	YDAIFTNSYRKVLGQLSARKLLQDIMSRQQGESNQERGARARL PHM
HADGVFTSSYRRILGQLSAKKYLESIM Secretin	HSDGFTTSELSRLRDSARLQRLLOGLV Glucagon
HSQGTFTSDYSKYLDSRRAQDFVQWLMNT PACAP	HSDGIFTDSYSRYRKQMAVKKYLA AVL GKRYKQVRVKNK
Helospectin	HSDATFTA EYSKLLAKLALQKYLESILGSSTSPRPPSS Helodermin

HSDAIFTQQYSKLLAKLALQKYLASILGSRTSPPP Mellltin GIGAVLKVLTTGLPALISWIKRKRQQ.

Drawing Description Text (2):

FIG. 1 illustrates the degradation by trypsin of the VIP expressed on and in liposomes (VIP liposome product) compared to a conventional VIP solution.

Drawing Description Text (3):

FIG. 2 illustrates the decrease in mean arterial blood pressure of hamsters treated with VIP liposome product and a conventional VIP solution.

Drawing Description Text (4):

FIG. 3 illustrates the change in mean arterial blood pressure of hamsters compared to dosage amounts of VIP liposome product and a conventional VIP solution.

Drawing Description Text (5):

FIG. 4 illustrates the percent release of (tyr.sup.10 -.sup.125 I)VIP bound on liposomes of bound VIP over time by dilution into solutions without VIP (closed circles) or excess unlabeled VIP (open circles).

Drawing Description Text (6):

FIG. 5 illustrates competitive inhibition of binding of (tyr.sup.10 -.sup.125 I)VIP on liposomes by unlabeled VIP.

Drawing Description Text (7):

FIG. 6 illustrates competitive inhibition of binding of (tyr.sup.10 -.sup.125 I)VIP on liposomes by having unlabeled VIP.

Drawing Description Text (8):

FIG. 7 illustrates pH dependency of binding of (tyr.sup.10 -.sup.125 I)VIP on liposomes.

Drawing Description Text (9):

FIG. 8 illustrates the degradation by proteolytic hydrolysis of the VIP bound on liposomes compared to a conventional VIP solution.

Detailed Description Text (2):

The invention relates to a method of delivering VIP to a target tissue of a mammal comprising the steps of forming a VIP liposome product where VIP is expressed on and in liposomes and administering a biologically effective amount of the VIP liposome product to the target tissue. A biologically effective amount refers to a concentration of VIP in the nanomolar to the micromolar range.

Detailed Description Text (3):

The VIP liposome product can be delivered intravenously, orally or transdermally where the transport system of the mammal delivers the VIP liposome product to the target tissue, or the VIP liposome product can be applied directly to the target tissue. Preferably, the VIP liposome product is delivered intravenously.

Detailed Description Text (5):

Calmodulin, the intracellular receptor for VIP and GRF can be included along with the peptides in the liposomes. This permits delivery of VIP-calmodulin complexes into the cells of the target tissue and thus enhances peptide biological effects.

Detailed Description Text (6):

The vasoactive intestinal polypeptide can be, for example, HSDAVFTDNYTRLRLRKQMAVKKYLNSILN-NH.sub.2, (SEE SEQ ID NO: 12) fragments or analogs thereof, or peptides homologous to VIP, such as GRF, PHI, PHM, PACAP, secretin and glucagon.

Detailed Description Text (9):

The VIP liposome product can be administered at significantly reduced dosage levels compared to conventional VIP and yet achieve efficacy equal to the conventionally administered VIP. Generally, the biologically effective amount of VIP is about 50 to 75 percent less by weight than the biologically effective amount for the VIP in an

encapsulated form. A biologically effective concentration of VIP is in the nanomolar to the micromolar range. Inclusion of calmodulin along with VIP at equimolar concentrations permits further reduction in the effective amount to 10% of that required using peptide administered by convention means.

Detailed Description Text (10):

VIP liposome product must be tested to determine the biologically effective amount required to achieve which comport with or exceed the results for conventionally administered VIP. For example, if the usual amount for VIP in conventional carriers is 20 mg, the VIP liposome product can achieve the same efficacy at about 10 mg to about 5 mg. Typically, the biologically effective amount for conventional VIP is 0.01 to 50 mg daily intravenously or 0.1 to 500 mg in enteric coated capsules, in humans.

Detailed Description Text (11):

The effects of VIP liposome product are also about 50 to about 100% longer lasting than conventional VIP.

Detailed Description Text (12):

The encapsulated VIP is significantly more resistant to hydrolysis than conventional VIP, which contributes to the increased longevity of encapsulated VIP.

Detailed Description Text (13):

The VIP is reversibly bound in the liposome.

Detailed Description Text (14):

The invention also relates to a VIP liposome product comprising cholesterol, phosphatidyl choline, and phosphatidyl glycerol.

Detailed Description Text (15):

The VIP can be bound in or on the liposome in a helix conformation. Preferably, the VIP is bound in a receptor reactive conformation whereby a biological potency of the VIP is enhanced.

Detailed Description Text (16):

A further embodiment relates to a method of making VIP having increased biological potency and decreased side effects comprising the steps of forming a VIP liposome product comprising cholesterol, phosphatidyl choline, and phosphatidyl glycerol.

Detailed Description Text (17):

Preferably, the VIP is bound in a receptor reactive conformation on or in the liposome.

Detailed Description Text (18):

Another embodiment relates to a method for controlling blood pressure in a mammal comprising the steps of administering an effective amount of a VIP liposome product comprising cholesterol, phosphatidyl choline, and phosphatidyl glycerol to the mammal.

Detailed Description Text (19):

The VIP liposome product can be used to treat, for example, abnormalities of gut motility, peptic ulceration, bronchial spasm including asthma, vascular conditions such as hypertension, impotence and ischaemia, mental disorders and baldness due to limiting blood flow.

Detailed Description Text (22):

The VIP release from liposomes according to the invention and the degradation of VIP bound on and in the liposomes was tested and compared to a conventional solution of VIP.

Detailed Description Text (23):

The hypotensive effect of VIP liposome product according to the invention was then compared to conventional VIP using Hamsters.

Detailed Description Text (24):

VIP liposome product was made using synthetic VIP (University of Florida, Gainesville)

which was purified by successive reversed-phased HPLC on a preparative C-18 column in triethylamine phosphate/acetonitrile and trifluoroacetic acid (TFA)/acetonitrile solvent systems. The peptide content of the purified VIP was 82% and an amino acid analysis confirmed full length VIP.

Detailed Description Text (25):

Radioiodination of VIP and purification of (tyr.sup.10 -.sup.125 I)VIP was done as described in Paul, S., Volle, D. J., Beach, C. M., Johnson, D. R., Powell, M. J. and Massey, R. J. (1989) Science 244, 1158-1162).

Detailed Description Text (26):

Liposomes were prepared by reverse evaporation from a mixture of egg yolk phosphatidylcholine, egg yolk phosphatidylglycerol and cholesterol (Sigma Chemical Co.) in a molar ratio of 1:4:5, using the method disclosed in Szoka, Jr., F. and Papahadjopoulos, Proc. Natl. Acad. Sci. USA 75, pp. 4194-4198 (1978). The phospholipids and cholesterol solution, 12 mM each, in 3 ml diethylether containing 3 mM synthetic VIP, a mixture of (tyr.sup.10 -.sup.125 I)VIP (about 100,000 CPM) and 3 mM unlabeled VIP or 0.2 nM of radioactive peptide alone was mixed with 1 ml 50 mM HEPES, pH 7.3 and sonicated. The diethylether was evaporated in vacuo to form liposomes in the solution. The resulting suspension was diluted with 10 ml 50 mM HEPES, and then centrifuged at 12,500.times.g for 7 minutes. The supernant was discarded and the pellet washed three times with a buffer containing 0.15M NaCl. Large liposomes were removed using a 1 .mu.m polycarbonate filter (Nucleopore). This method permits expression of VIP on the surface of liposomes and within liposomes.

Detailed Description Text (28):

The content of VIP in the liposomes was measured by two methods. In the first method, (tyr.sup.10 -.sup.125 I)VIP (0.2 nM) mixed with 3 mM unlabeled VIP was encapsulated in liposomes and aliquots of the final liposome suspension were counted for (tyr.sup.10 -.sup.125 I)VIP radioactivity (70% efficiency). In the second method, liposomes containing unlabeled VIP were solubilized with sodium dodecylsulfate (1% w/v), the extract was diluted to 0.01% SDS with 0.1% TFA in water and extracted on a Sep-Pak C18 cartridge (Waters), and the VIP content of the bound fraction was measured by radioimmunoassay as described in Paul, J. Chou and E. Kobota, Life Sci., 41, pp. 2373-2380 (1987).

Detailed Description Text (29):

The degradation of VIP bound in the liposomes was tested and compared to a conventional solution of VIP as follows.

Detailed Description Text (30):

(tyr.sup.10 -.sup.125 I)VIP in liposomes according to the invention, 17,700 cpm/0.67 .mu.mole phospholipids, and an equivalent amount of (tyr.sup.10 -.sup.125 I)VIP dissolved in 50 mM HEPES, pH 7.3, containing 0.5% bovine serum albumin (BSA, RIA grade; Sigma) were treated with 30 nM of trypsin from bovine pancreas (Sigma) at 23.degree. C. Triton X-100 (Sigma) was added to 1% w/v to solubilize the liposomes. The detergent concentration was reduced to 0.25% with buffer.

Detailed Description Text (31):

Incubation 23.degree. C. of the encapsulated (tyr.sup.10 -.sup.125 I)VIP (solid circle) with trypsin over 60 minutes revealed little or no peptide hydrolysis, as shown in FIG. 1. In comparison, 80% of control (tyr.sup.10 -.sup.125 I)VIP (hollow circle) in solution was digested within 10 minutes by the enzyme, as shown in FIG. 1. The values in FIG. 1 are means of 3 replicates.+-.standard deviation.

Detailed Description Text (32):

The rate of trypsin-catalyzed hydrolysis of pro-phe-arg-methyleoumarinamide was essentially identical in the absence and presence of empty liposomes, which was measured as described S. Paul, et. al., J. Biol. Chem., 267, pp. 13142-13145 (1992). The reduced hydrolysis of encapsulated VIP by trypsin, therefore, was not due to a non-specific inhibitory effect of the liposomes.

Detailed Description Text (33):

The peptide degradation by hydrolysis was measured by determining the trichloroacetic acid-soluble radioactivity of (tyr.sup.10 -.sup.125 I)VIP as described in the Science

244:1158-1162 (1989) Supra.

Detailed Description Text (34):

The release of VIP from the liposomes was determined as follows.

Detailed Description Text (35):

The peptide release from liposomes containing (tyr.sup.10 -.sup.125 I)VIP, approximately 20,000 cpm, kept at 4.degree. C. in 50 mM HEPES, pH 7.3, containing 0.02% NaN.sub.2 was determined by centrifugation of aliquots of the suspension at 12,400.times.g for 15 minutes and measurement of radioactivity in the supernatants.

Detailed Description Text (36):

The leakage of (tyr.sup.10 -.sup.125 I)VIP from the liposomes stored in buffer at 4.degree. C. for 14 days was negligible, <2% of available radioactivity. Microscopic examination did not reveal breakdown of the liposomes over this time period.

Detailed Description Text (37):

The hypotensive effect of VIP liposome product according to the invention was compared to conventional VIP using male golden Syrian hamsters (120-130 g body weight) as follows.

Detailed Description Text (40):

In each hamster, 1 ml aliquots of increasing concentrations of VIP dissolved in 0.15M sodium chloride or encapsulated in liposomes (1 nmol VIP/0.12 .mu.mol phospholipids) were infused intravenously for 7 minutes.

Detailed Description Text (45):

Encapsulated VIP prepared from a solution of tracer (tyr.sup.10 -.sup.125 I)VIP and 3 mM unlabeled VIP in the liposomes contained 8.9% of available peptide, corresponding to encapsulation of 0.008 mole VIP/mole phospholipid, measured on the basis of uptake of the radioactive peptide. This was measured by repeatedly washing the liposomes with saline to remove free peptide followed by determination of radioactivity in a gamma counter. Measurement of the amount of non-radioactive encapsulated VIP by radioimmunoassay yielded essentially identical values.

Detailed Description Text (46):

The effect on blood pressure was determined by measuring the magnitude of reduction in mean arterial blood pressure (MAP) as a function of time following infusion of VIP dissolved in saline or encapsulated in liposomes. The hamsters did not display detectable untoward effects during infusion of dissolved VIP or empty liposome preparations. In addition, no leaky site formation was observed in the check pouch microcirculation of the hamsters.

Detailed Description Text (47):

FIG. 2. shows the decrease in MAP as a function of time during and following administration of VIP encapsulated in liposomes, 0.008 peptide/mole phospholipid, or dissolved in saline. The dosage level was 1.0 nmole for the encapsulated VIP and the VIP in 0.15M NaCl (saline) solution. The peptide infusion time was 7 minutes (solid bar). MAP values for animals treated with VIP in saline (hollow circles) or in liposomes (solid circles) were 93.0 and 93.4 mm Hg. The data is the means from 5 hamsters (.+-.SEM) in each group. In FIG. 2, (*) represents $P < 0.05$ versus VIP in saline at corresponding time points, with one-tailed t-test for unpaired observations.

Detailed Description Text (48):

As shown in FIG. 2, a significant decrease in MAP was observed at 5 minutes ($p < 0.05$, one-tailed t-test) and marginally significant decreases were observed at other time points between 3 and 7 minutes ($p < 0.1$). In comparison, infusion of VIP liposome product produced a significant decrease in MAP within 1.5 minutes. The magnitude of the maximum reduction in MAP was approximately 3.5 fold greater, and the duration of the hypotensive effect was more prolonged than with VIP dissolved in saline. At a dose of 1 nmole per hamster, VIP dissolved in saline only induced a weak and transient decrease in MAP, as shown in FIG. 2.

Detailed Description Text (49):

FIG. 2 illustrates that the effect of the VIP was fully reversible, indicated by return of the arterial blood pressure values to the pre-infusion baseline (VIP dissolved in saline, 9 minutes; VIP liposome product, 16 minutes).

Detailed Description Text (50):

FIG. 3 illustrates the effect of VIP liposome product (0.008 mole peptide/mole phospholipid; solid bars) compared to VIP dissolved in 0.15M NaCl (hollow bars) on the mean arterial pressure (MAP) in anesthetized hamsters. The values are means \pm SEM (n=5). *p<0.05 versus VIP in saline.

Detailed Description Text (51):

The above data illustrates that the hypotensive effect of VIP in saline or encapsulated in liposomes is concentration dependent. The data further illustrates that the decrease in MAP following infusion of 0.5 nmole or 1 nmole VIP in liposomes was significantly greater than equivalent amounts of control VIP in saline (p<0.05).

Detailed Description Text (52):

At 3 nmole VIP, the values for control and peptide liposome product were not significantly different, because the dose produced a saturating peptide concentration.

Detailed Description Text (53):

This example illustrates that the hypotensive effect of VIP is significantly enhanced by presence of the peptide in and on liposomes. This is evident both by a prolongation of the hypotensive effect and an increase in the magnitude of the effect observed using VIP liposome product compared to control VIP solutions. Administration of empty liposomes had no significant effects on mean arterial blood pressure. There was no evidence of microvascular injury following administration of empty liposomes or VIP liposome product. In addition, the hypotensive effects of VIP alone or VIP liposome product were fully reversible. Collectively, the data demonstrates that non-specific tissue injury was not a contributory factor in the enhanced hypotensive effect of VIP contained in or on liposomes.

Detailed Description Text (54):

The reduced trypsinolysis of VIP liposome product demonstrates that diminished degradation of VIP could underline the increased duration of its hypotensive effect in Hamsters. In view of the amphipathic character of VIP, the applicants believe that the lipids bind VIP and enhance its biological potency by stabilizing a receptor-reactive conformation. This is supported by observations that VIP penetrates protein-free bilayers as described in Y. Noda, et. al., FASE B. Journal 7, 1053 (1993), and anionic lipids like phosphatidyl glycerol induce helix formation in the peptide detected by circular dichroism studies disclosed in R. M. Robinson, et. al., Bipolymers, 21, pp. 1217-1228 (1982). A correlation between the helix forming tendencies of VIP analogues and their biological potencies is described in G. F. Musso, et. al., Biochemistry, 27, pp. 8174-8181 (1988).

Detailed Description Text (56):

Demonstration of Lipid Bilayer Binding and Penetration by VIP

Detailed Description Text (57):

The VIP release from liposomes according to the invention and the degradation of VIP bound in the liposomes was tested and compared to a conventional solution of VIP.

Detailed Description Text (64):

Synthetic VIP

Detailed Description Text (65):

(HSDAVFTDNYTRLRLKQMAVKYLSILN-NH₂; SEQ ID NO: 12; peptide content 81%, Bachem) was labeled with ¹²⁵I using chloramine-T. The (tyr.^{sup.10} - ^{sup.125}I) VIP was separated by reversed-phase high performance liquid chromatography (RP-HPLC) and identified by N-terminal radiosequencing as described in Example 1. The specific activity of the peptide was 2000 Ci/mmole.

Detailed Description Text (66):

Unlabeled VIP synthesized at the University of Florida, Gainesville and purified by

preparative RP-HPLC on a C-18 column was used in some of the examples. The peptide content of this preparation was 83% and the purity was confirmed by amino acid analysis and automated N-terminal sequencing at the University of Nebraska Protein Structure Core Facility.

Detailed Description Text (70):

The resistance to hydrolysis of liposome-bound and free (tyr.sup.10 -.sup.125 I)VIP was tested by adding Trypsin (Sigma) in 50 mM HEPES, pH 7.3 thereto. The liposomes were centrifuged to separate released radioactivity, solubilized in 20% acetonitrile, BSA was added to 0.1% (w/v) as carrier and the TCA-insoluble radioactivity (undegraded VIP) was determined according to Paul, S., Volle, D. J., Beach, C. M., Johnson, D. R., Powell, M. J. and Massey, R. J. (1989) Science 244, 1158-1162.

Detailed Description Text (71):

The levels of VIP hydrolysis determine by this method correlated with those observed by separation of the reaction mixtures by RP-HPLC ($r > 0.9$) as reported in Paul, S., Mei, S., Mody, B., Eklund, S. H., Beach, C. M., Massey, R. J. and Hamel, F. (1991) J. Biol. Chem. 266, 16128-16134. Hydrolysis of pro-phe-arg-MCA (Peptides International) was determined as the fluorescence of the coumarin leaving-group (.sup..lambda. em 460 nm, .sup..lambda. ex 370 nm).

Detailed Description Text (74):

Binding of carboxyfluorescein (CF; 100 nM; Eastman Kodak) was measured using experimental conditions identical to those used for VIP.

Detailed Description Text (75):

The ESR was taken as follows. Lipid liposomes were prepared as described above, except that 5-doxyl-stearic acid (5-DS) or 16-doxyl-stearic acid (16-DS) (Sigma) was included in the phospholipid solution in ether to give a spin label concentration of 0.2 nM (spin label/phospholipid molar ratio, 1.60). The labeled liposomes were washed, and incubated with VIP in 0.2 ml 50 mM HEPES, pH 7.3, 0.5% BSA (w/v) at 23.degree. C. for 60 min. After incubation, the labeled liposomes were centrifuged at 12,000 rpm for 15 min and the resulting pellet was resuspended in 100 .mu.l of 50 mM HEPES, pH 7.3.

Detailed Description Text (77):

The binding of the VIP to the liposome was determined as follows. Unilamellar lipid liposomes were prepared by reverse evaporation and assayed for binding of radiolabeled VIP, as described above. BSA was included in the assay diluent to saturate nonspecific polypeptide binding sites in the lipid liposomes and the polypropylene surface of the reaction tubes.

Detailed Description Text (78):

Increasing concentrations of preformed lipid liposomes (2.5-45.6 mM P.sub.i) displayed increasing binding of (tyr.sup.10 -.sup.125 I)VIP, up to 56.6% of available peptide (0.42 nM). The results are shown in Table 1.

Detailed Description Text (79):

Under conditions identical to those used for VIP, the liposomes took up very small amounts of carboxyfluorescein, which is a small polar molecule (376 daltons) often used to study the integrity of lipid liposomes.

Detailed Description Text (80):

In contrast, liposomes formed in the presence of VIP and CF contained somewhat greater concentrations of CF than VIP. The latter values represent encapsulation of VIP and CF within liposomes. Taken together, the data illustrates that the observed association of VIP with the liposome does not represent entrapment due to liposome breakage and resealing.

Detailed Description Text (81):

Values are means.+-.s.d. Probe-binding was with pre-formed liposomes (2.3 mM P.sub.i) and 100 nM CF or 0.2 nM (tyr.sup.10 -.sup.125 I)VIP mixed with 100 nM unlabeled peptide. Encapsulation was by making liposomes from lipid solutions (2.6 mM P.sub.i) containing 2.5 .mu.M CF or 1.7 nM (Tyr.sup.10 -.sup.125 I)VIP mixed with 2.5 .mu.M unlabeled VIP. Free probes were removed by three washes with 50 mM HEPES, pH 7.3,

containing 0.5% BSA. CF values were determined by fluorimetry after solubilization of liposomes, and VIP values, by measurement of liposome-associated radioactivity.

Detailed Description Text (82):

Incubation of (Tyr.sup.10 -.sup.125 I)VIP-liposome complexes in the presence of excess unlabeled VIP (2 mM) resulted in release of approximately 90% of the initial liposome-associated peptide and steady-state conditions were reached at the earliest time-point examined (30 min), showing that the peptide was not irreversibly sequestered in the lipid bilayers. In the absence of exogenous unlabeled peptide, slow release of approximately 50% of the liposome-associated peptide over 24 h was observed, as shown in FIG. 4.

Detailed Description Text (83):

The reversibility of binding of VIP by lipid liposomes was measured as followed. Liposomes (3.3 mM 0) were labeled with (Tyr.sup.10 -.sup.125)VIP (0.11 nM), washed to remove free peptide and incubated in 0.2 ml buffer in the absence (hollow circle) or presence of (black circle) of 2 mM unlabeled VIP for varying time-periods (20.degree. C.). The remaining liposome-associated radioactivity was determined and expressed as % of initial bound peptide (35,410 CPM).

Detailed Description Text (84):

The partitioning of (Tyr.sup.10 -.sup.125 I)VIP into the liposomes was competitively inhibited by increasing concentrations of unlabeled VIP (IC₅₀ 560 .mu.M;), as shown in FIG. 5. A plot of bound versus available peptide can be fitted to the equation for a rectangular hyperbola typical of a saturation isotherm [$y = (B_{\text{max}} \cdot x) / (1 + K_d + x)$], where x and y are available and bound peptide, respectively].

Detailed Description Text (85):

FIG. 5 illustrates the results of the competitive inhibition of binding of (Tyr.sup.10-.sup.125)VIP (0.26 nM) by the liposomes (2.4 mM P.sub.i) by unlabeled VIP (10 nM-1 mM). Data are means.+-.s.d expressed as % of available radiolabeled peptide.

Detailed Description Text (87):

In a control experiment performed to eliminate the possibility of artifacts due to use of radiolabeled peptide, lipid liposomes (2 mM P.sub.i) were permitted to bind unlabeled VIP (0.2 mM), the liposomes were solubilized with 1% SDS and extracted on a C-18 cartridge and analyzed by RP-HPLC on a C-18 column according to Paul, S., Volle, D. J., Beach, C. M., Johnson, D. R., Powell, M. J. and Massey, R. J. (1989) Science 244, 1158-1162. A peptide peak displaying the characteristic retention time of authentic VIP was observed. The amount of peptide recovered in this peak, estimated by its absorbance at 214 nm, was 76% of the value predicted from radiolabeled VIP-binding experiments.

Detailed Description Text (88):

The binding of VIP (100 nM) by electrically neutral and negative liposomes prepared from PC/CH and PG/PC/CH, respectively, was compared. In each case, the levels of peptide binding increased within increasing concentration of the liposomes. The values of % VIP bound.+-.s.d./ .mu.mol P.sub.i were, PG/PC/CH liposomes, 26.2+3.4; PC/CH liposomes, 12.6+-.1.5. Provided that minor differences in fatty acid composition of the phospholipids are not an interfering factor, this data is consistent with a stabilizing role for electrostatic interactions between acidic lipid head groups and VIP, which is a basic peptide rich in lys and arg residues. The inclusion of cholesterol, an agent that can be expected to decrease bilayer fluidity at the temperatures used in this study, as reported in Demel, R. A. and DeKruyff, B. (1976) Biochim. Biophys. Acta 457, 109-132), did not influence the binding of VIP by the liposomes (26.2% and 24.9% VIP bound/ .mu.mole P.sub.i PC/PG/CH and by PC/PG liposomes respectively.)

Detailed Description Text (89):

The solvent effects on the encapsulated VIP were measured as follows. In particular, pH-dependent binding of (Tyr.sup.10 -.sup.125)VIP (0.14 nM) by lipid liposomes (2.1 mM P.sub.i) was assayed at several pH values in a constant ionic strength buffer (25 mM ethanolamine, 25 mM Tris, 50MM morpholinethane sulfonic acid) as disclosed in Ellis, K. J. and Morrison, J. F. (1982) Meth. Enzymol. 87, 406-427). The results are

shown in FIG. 7, which illustrates that the binding was low at the extreme pH values and optimal binding was observed at near-neutral pH (pH 6-8). The data are means \pm s.d from a representative experiment.

Detailed Description Text (90):

Treatment of (Tyr.sup.10 -.sup.125 I)VIP-liposome complexes with 25 mM EDTA, 1 mM HCl, or 1M NaCl caused little or no release of the bound peptide, as shown in Table 2. At alkaline pH (1M NaOH), a small but significant proportion (16) of the bound radioactivity was reproducibly released. Dissolution of the liposomes with SDS produced near-complete peptide release into the supernatant, reflecting, presumably, uptake of the peptide into mixed detergent-lipid micelles.

Detailed Description Text (91):

Lipid liposomes (4 mM P.sub.i) were permitted to bind (Tyr.sup.10 -.sup.125 I)VIP (1 nM), washed extensively to remove unbound radioactivity and then treated twice with 1 ml of the indicated solutions for 10 min (23.degree. C.). Released radioactivity was determined in the pooled supernatant obtained by centrifugation. Values are % of initial liposome-bound radioactivity (76,300 CPM), corrected for peptide release in control incubations performed in 50 mM HEPES, pH 7.3 (4.2 \pm .3.4%).

Detailed Description Text (92):

The degradation of VIP liposome product was measured. With increasing trypsin concentration, increasing hydrolysis of free (Tyr.sup.10 -.sup.125 I)VIP after 45 min of incubation (up to 80% of available peptide) was evident, as shown in FIG. 8. In the case of liposome-bound (Tyr.sup.10 -.sup.125 I)VIP, most of the radioactivity remained associated with the liposomes treated with 1 nM, 5 nM and 26 nM trypsin (82, 83 and 73% of initial radioactivity, respectively). Compared to the free peptide, a smaller proportion of the liposome-associated radioactivity recovered after the trypsin-treatment was TCA-soluble, suggesting a reduced susceptibility to proteolysis. To test for nonspecific inhibition of enzyme activity, a methylcoumarinamide (MCA) conjugate of a basic peptide (pro-phe-arg-MCA) (15 .mu.M) (SEE SEQ ID NO: 13) was incubated with trypsin (10 nM) in the absence and presence of the liposomes (1 mM p.sub.i) for 30 minutes, followed by removal of the liposomes by centrifugation. The observed increases in fluorescence intensity in the presence and absence of the liposomes were similar (868 FU and 885 FU, respectively).

Detailed Description Text (93):

FIG. 8 shows decreased proteolytic hydrolysis of liposome-bound VIP (hollow circle) compared to free VIP (black circle). Liposomes (4.2 mM P.sub.i) were labeled with (Tyr.sup.10 -.sup.125 I)VIP (0.37 nM), washed with buffer to remove free peptide and treated with varying concentrations of trypsin for 45 min in 50 mM HEPES, pH 7.3. Released radioactivity was removed by centrifugation and aspiration of the supernatant. Liposomes were solubilized with acetonitrile (30%). TCA was added to 10% and BAS to 0.1%, and acid-soluble radioactivity was measured to determine the degree of hydrolysis. Data are means \pm s.d expressed as % of initial liposome-associated peptide (28,290 CPM) corrected for TCA-soluble radioactivity observed in the absence of trypsin (10%).

Detailed Description Text (94):

The VIP effects on bilayer fluidity were determined. ESR spectra of 5-DS and 16-DS labeled lipid liposomes were first obtained. These spin labels are commonly used to measure the fluidity close to the surface (5-DS) and core (16-DS) of lipid bilayers (e.g., 117.22). With increasing VIP/lipid molar ratios, progressively decreasing values of the motion parameter .tau..sub.o were evident using 16-DS labeled liposomes, as shown in Table 3.

Detailed Description Text (95):

In contrast, the order parameter S computed using the 5-DS probe tended to increase by exposure to VIP, with the effect reaching statistical significance at a concentration of 500 .mu.M VIP. This data suggests a pronounced VIP-induced increase of fluidity in the hydrophobic core of the bilayer and a relatively small but significant decrease in fluidity close to the bilayer surface.

Detailed Description Text (97):

The general conclusion from this Examples is that VIP can bind and penetrate the

hydrophobic core of model lipid bilayers. The binding was saturable and reversible at neutral pH. The nominal values of the partition constant derived from the binding isotherm (1.4×10^3 M⁻¹) was in the same range as that reported for another amphophilic peptide, melittin, in Beschiaschvili, G. and Seelig, J. Biochemistry 29, 52-58. The apparent binding capacity at saturating VIP concentrations was 1 mol VIP/12.5 mol phospholipid.

Detailed Description Text (98):

Electrostatic interactions probably play a role in the observed VIP binding by PG containing negatively-charged liposomes, because VIP is a basic peptide. However, several considerations indicate that electrostatic binding alone cannot explain the observed interaction because: (a) Neutral liposomes also displayed VIP binding activity, in contrast to observations that several other basic peptides are bound only by negatively charged liposomes as reported in Mosior, M., and McLaughlin, S. (1992) Biochemistry 31, 1767-1773; (b) VIP bound by PG/PC/CH liposomes was released minimally or not at all by acid, alkali and high ionic strength solvent; (c) the optimal pH for VIP binding by negatively charged liposomes was in the neutral range, unlike alkaline pH optima observed for the binding of basic proteins like lysozyme by similar liposomes as disclosed in Bergers, J. J., Vingerhoeds, M. H., van Bloois, L., Herron, J. N., Janssen, L. H. M., Fischer, M. J. E. and Crommelin, D. J. A. (1993) Biochemistry 32, 4641-4649; and, (d) treatment with VIP produced significant changes in the mobility of nitroxide spin-labeled stearic acid probes incorporated in the lipid liposomes. These considerations are consistent with the hypothesis of electrostatic binding of VIP to phospholipid head groups combined with penetration of a hydrophobic region(s) of the peptide into the bilayer.

Detailed Description Text (99):

Estimates of the fluidity at different depths in the bilayer can be obtained by measuring the motion of spin labels placed at varying distance from the carboxyl group of fatty acid probes (e.g., 5-DS and 16-DS used in the present study). Binding of polypeptides by membranes can lead to qualitatively similar or opposing effects on fluidity at different depths in the bilayer. See Boggs, J. M. (1983) in Membrane Fluidity in Biology (Aloia, R. C. ed.) Vol II, pp. 89-130, Academic Press, N.Y. for review. In this Example, the association of VIP with the liposomes was accompanied by a small but significant increase in the order parameter S for 5-DS and a striking decrease in the motion parameter τ_0 for 16-DS, suggesting decreased fluidity close to the surface of the bilayer and increased fluidity in its core.

Detailed Description Text (100):

Myelin basic protein, as disclosed in Boggs, J. M., Wood, D. D. and Moscarello, M. A. (1981) Biochemistry 20, 1065-1073, has been previously described to produce similar effects on the fluidity characteristics in the bilayer core and surface. The decrease in 5-DS mobility following exposure to VIP may derive from electrostatic binding at phospholipid head groups. In analogy with the mechanism proposed for myelin basic protein, penetration of a hydrophobic region of VIP into the bilayer may produce a larger volume increase in the core of the bilayer compared to its surface, accounting for the increased mobility (decreased τ_0) to the 16-DS probe.

Detailed Description Text (101):

The lipid binding properties of VIP are not entirely unexpected in the context of its known structural characteristics. Modeled as a π -helix (4.4 residues/turn) or a twisted α -helix (Musso, G. F., Patthi, S., Ryskamp, T. C., Provow, S., Kaiser, E. T. and Velicelebi, G. (1988) Biochemistry 27, 8174-8181), the cationic and apolar residues of VIP segregate onto the opposite faces of the helix. α -helical amphiphilic peptides are well documented to bind lipid bilayers. For example, depending upon the experimental conditions, melittin and alamethicin may bind along the surface of lipid bilayers or form bilayer-spanning aggregates, as reported in Sansom, M. S. P. (1991) Prog. Biophys. Molec. Biol. 55, 139-235. Similarly, peptides in which α -helix distortions permit segregation of apolar and polar residues are known to bind lipid bilayers, as reported in Karle, I. L., Flippen-Andersen, J., Uma, K. and Balaram, P. (1988) Proc. Natl. Acad. Sci. U.S.A. 85, 299-303. In the case of VIP, the central segment spanning residues 12-21 contains cationic residues interspersed with apolar ones, has a high propensity for helix formation, as reported in Robinson, R. M., Dlakene, Jr., E. W. and Mattice, W. L. (1982) Biopolymers 21, 1217-1228; Hamed, M. M., Robinson, R. M. and Mattice, W. L. (1983) Biopolymers 22,

1003-1021; and Bodanszky, M. Bodanszyk, A., Klausner, Y. S. and Said, S. I. (1974) Bioorganic Chem. 3, 133-140), and could be important in formation of peptide aggregates with membrane binding activity. All of the trypsin-sensitive bonds in VIP are located in this region (R.sup.12 -L.sup.13, R.sup.14 -K.sup.15, K.sup.15 -Q.sup.16 K.sup.20 -K.sup.21, K.sup.2 -Y.sub.22). The observation of diminished trypsinolysis of liposome-associated VIP is consistent with burial of this segment into the lipid bilayer.

Detailed Description Text (102):

The biological actions of VIP are remarkably diverse and this neuropeptide activates apparently unrelated signal transducing systems reviewed in Said, S. I. (1984) Peptides 5, (Suppl. 1) 149-150; Paul, S. and Ebadi, M. (1993) Neurochem. Int. 23, 197-214. VIP is a known modulator of synaptic transmission, smooth muscle tone, transmembrane water and ion flux, neuroendocrine secretion and T- and B-lymphocyte immunological activities. There are several ways in which VIP-lipid bilayer interactions may be important.

Detailed Description Text (103):

In the absence of definitive evidence concerning the mechanism or removal and inactivation of VIP, it was commonly assumed that proteolytic degradation is responsible for termination of the biological effects of the peptide. In this Example, it has been shown that within the limits of saturability of the system, large proportions of the radiolabeled VIP (up to 60%) were bound by lipid liposomes, indicating that partitioning into membranes could be a factor governing the availability of soluble peptide in extracellular fluids.

Detailed Description Text (104):

Second, binding of VIP by lipid particles or soluble lipids may stabilize the peptide to proteolysis and permit its delivery to distant target cells.

Detailed Description Text (105):

Third, partitioning of VIP into lipid bilayers may restrict the peptide into a specific conformation(s) and thus modify its interaction with membrane receptors.

Detailed Description Text (106):

Finally, local concentration of VIP within neuronal storage liposomes and at the site of release from nerve endings may be sufficient to directly modulate membrane function via changes in bilayer fluidity.

Detailed Description Text (108):

Liposomes containing mixtures of VIP and calmodulin were prepared in the manner set forth above in Examples 1. The measurement of hypotensive activity of the component mixtures set forth in Table 4 below were likewise done in manners set forth above. Arterial blood pressure readings shown below were taken five (5) minutes after the start of infusion of the component mixtures.

Detailed Description Paragraph Table (1):

TABLE 1	Probe Binding, nM				Encapsulation, nM			
		<u>VIP</u>	20.5	+- 1.0	37.5	+- 5.0	CF	0.01 +-.
0.001	82.5	+- 7.5						

Detailed Description Paragraph Table (2):

TABLE 2	Treatment % <u>VIP</u> released							
		25 mM EDTA	8.1	+- 10.0	1 mM HCl	3.0	+- 3.5	
1 M NaCl	2.7	+- 3.0	1 mM NaOH	15.9	+- 4.0	1% SDS	81.1	+- 9.6

Detailed Description Paragraph Table (3):

TABLE 3	S .tau..sub.o, X10.sup.-10 sec <u>VIP</u> ,							
.mu.M (5-DS) (16-DS)								
		0	0.751	+- 0.014	136.06			
+- 22.01	200	0.755	+- 0.012	121.71	+- 32.41	300	0.771	+- 0.017
9.31*	500	0.801	+- 0.031*	88.43	+- 2.65*			

Detailed Description Paragraph Table (4):

TABLE 4	Mean Arterial Blood Pressure Heart							
---------	------------------------------------	--	--	--	--	--	--	--

Rate (mm Hg) (min) _____ CONTROL 111.7 324 LIPO
117.0 318 1 nmol VIP + LIPO 53.3 408 1 nmol VIP + LIPO + 20.0 432 1 nmol calmodulin

CLAIMS:

1. A method of delivering a vasoactive intestinal polypeptide liposome product to a target tissue comprising the steps of;

encapsulating said vasoactive intestinal polypeptide (VIP) under conditions which result in VIP being expressed both on and in liposomes in a receptor active conformation to form a VIP liposome product; and

administering a biologically effective amount of said VIP liposome product to said target tissue.

5. The method according to claim 1, wherein said VIP liposome product is administered intravenously to treat hypertension.

6. The method according to claim 1, wherein said administration step includes the administration of a biologically effective amount of calmodulin along with the VIP liposome product.

7. The method of claim 6, wherein the administration step is performed with a preformed VIP-Calmodulin mixture expressed in and on liposomes.

8. A vasoactive intestinal polypeptide (VIP) liposome product wherein VIP is encapsulated in liposomes under conditions which result in VIP being expressed both on and in the liposomes in a receptor active conformation wherein the liposomes contain cholesterol, phosphatidyl choline, and phosphatidyl glycerol.

10. The vasoactive intestinal polypeptide (VIP) liposome product according to claim 8, wherein said receptor active conformation is helical.

11. A vasoactive composition comprising a mixture of a biologically effective amount of a VIP and calmodulin liposome product wherein VIP and calmodulin are encapsulated in liposomes under conditions which result in VIP and calmodulin being expressed both on and in the liposomes wherein VIP is in a receptor active conformation.

12. A method of making a vasoactive intestinal polypeptide liposome product comprising the steps of;

forming said vasoactive intestinal Polypeptide (VIP) liposome product under conditions which result in VIP being encapsulated in liposomes under conditions which result in VIP being expressed both on and in the liposomes in a receptor active conformation.

15. A method for controlling blood pressure in a mammal comprising the steps of;

administering an effective amount of the VIP liposome product according to claim 8 or the composition of claim 11 to said mammal.

16. A method of delivering a vasoactive intestinal polypeptide (VIP) family member liposome product to a target tissue comprising the steps of;

encapsulating said VIP family member under conditions which result in said VIP family member being expressed both on and in liposomes in a receptor active conformation to form a VIP family member liposome product, wherein said VIP family member is selected from the group consisting of vasoactive intestinal polypeptide, growth hormone releasing factor, pituitary adenylate cyclase activating peptide, secretin, peptide histidine methionine, helodermin, helospectin, and glucagon; and

administering a biologically effective amount of said VIP family member liposome product to said target tissue.

18. A vasoactive intestinal polypeptide (VIP) family member liposome product wherein said VIP family member is encapsulated in liposomes under conditions which result in said VIP family member being expressed both on and in the liposomes in a receptor active conformation wherein the liposomes contain cholesterol, phosphatidyl choline, and phosphatidyl glycerol; wherein said VIP family member is selected from the group consisting of vasoactive intestinal polypeptide, growth hormone releasing factor, pituitary adenylate cyclase activating peptide, secretin, peptide histidine methionine, helodermin, helospectin, and glucagon.

19. A method of making a vasoactive intestinal polypeptide (VIP) family member liposome product comprising the steps of;

forming said VIP family member liposome product under conditions which result in VIP family member being encapsulated in liposomes under conditions which result in VIP family member being expressed both on and in the liposomes in a receptor active conformation; wherein said VIP family member is selected from the group consisting of vasoactive intestinal polypeptide, growth hormone releasing factor, pituitary adenylate cyclase activating peptide, secretin, peptide histidine methionine, helodermin, helospectin, and glucagon.

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L3: Entry 41 of 78

File: USPT

Jun 27, 1995

DOCUMENT-IDENTIFIER: US 5428015 A

TITLE: Vasoactive intestinal polypeptide analogues and use thereof

Abstract Text (4):

Each of the VIP analogues is employed as an effective ingredient for various medicines and a hair tonic, and more particularly curing an asthma and impotence.

Brief Summary Text (4):

The VIP analogue according to the invention can be used as an effective ingredient For various medicines, for instance an agent for curing asthma, anaphylaxis, hyperpiesia, impotence and the like, as well as a hair tonic.

Brief Summary Text (18):

Among of those biological activities, the VIP has been expected as the drugs for curing an asthma and impotence, by utilizing the bronchodiliatating action and the atonic action on smooth muscle of corpus cavernosum, respectively. A structural characteristic of the VIP lies in that there is an amide structure at C-terminal, which has been estimated as an indispensable matter for developing the biological activities of VIP.

Brief Summary Text (26):

An additional but important object of the invention is to provide a pharmaceutical composition for curing various diseases, and more particularly asthma and impotence, which contains as an effective ingredient the VIP analogue.

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L3: Entry 43 of 78

File: USPT

Dec 27, 1994

US-PAT-NO: 5376637

DOCUMENT-IDENTIFIER: US 5376637 A

TITLE: Pharmaceutical preparation containing vasoactive intestinal polypeptide or its analogue

DATE-ISSUED: December 27, 1994

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
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Kurono; Masayasu	Nagoya			JP
Mitani; Takahiko	Nagoya			JP
Sato; Makoto	Nagoya			JP
Takahashi; Haruo	Nagoya			JP
Ohwaki; Hiroyuki	Nagoya			JP

US-CL-CURRENT: 514/12; 514/13, 514/14, 514/15, 514/16, 530/324, 530/327, 530/328

CLAIMS:

What is claimed is:

SEQUENCE LISTING

(1) GENERAL INFORMATION:
(iii) NUMBER OF SEQUENCES: 3
(2) INFORMATION FOR SEQ ID NO:1:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 28 amino acids
(B) TYPE: amino acid
(D) TOPOLOGY: linear
(ii) MOLECULE TYPE: peptide
(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:
HisSerAspAlaVal PheThrAspAsnTyrThrArgLeuArgLysGln
151015
MetAlaValLysLysTyrLeuAsnSerIleLeuAsn
20 25
(2) INFORMATION FOR SEQ ID NO:2:
(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 29 amino acids
(B) TYPE: amino acid
(D) TOPOLOGY: linear
(ii) MOLECULE TYPE: peptide
(ix) FEATURE:
(A) NAME/KEY: Peptide
(B) LOCATION: 17
(D) OTHER INFORMATION: /note="Xaa is a residue of an amino
acid other than methionine (met)"
(ix) FEATURE:

(A) NAME/KEY: Peptide
 (B) LOCATION: 29
 (D) OTHER INFORMATION: /note="Xaa is homoserine, homoserine- lactone, amidized homoserine, a residue reacted homoserine-lactone with a primary alkyl amine having carbon atoms not exceeding 20, or an optional polypeptide chain containing an amidized homoserine at the C- terminal"
 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:
 HisSerAspAlaValPheThrAspAsnTyrThrArgLeuArgLysGln
 151015
 XaaAlaValLysLysTyrLeuAsnSerIleLeuAsnXaa
 2025
 (2) INFORMATION FOR SEQ ID NO:3:
 (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 29 amino acids
 (B) TYPE: amino acid
 (D) TOPOLOGY: linear
 (ii) MOLECULE TYPE: peptide
 (ix) FEATURE:
 (A) NAME/KEY: Peptide
 (B) LOCATION: 29
 (D) OTHER INFORMATION: /note="Xaa is a homoserine or homoserine- lactone residue"
 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:
 HisSerAspAlaValPheThrAspAsnTyrThrArgLeuArgLysGln
 151015
 LeuAlaValLysLysTyrLeuAsnSerIleLeuAsnXaa
 2025

1. A method for treating asthma comprising administering to a patient in need of such treatment an effective amount of a pharmaceutical composition comprising an amount of a vasoactive intestinal polypeptide (VIP) analogue (SEQ ID NO: 2) selected from the group consisting of [L-Leu.sup.17]-VIP-Hse, [L-Leu.sup.17]-VIP-Hse-NH.sub.2, [L-Leu.sup.17]-VIP-Hse-NH(CH.sub.2).sub.9 CH.sub.3, [L-Leu.sup.17]-VIP-Hse-NH(CH.sub.2).sub.19 CH.sub.3 and a pharmaceutically acceptable salt thereof, effective to treat asthma, in combination with a surfactant and a pharmaceutically acceptable carrier.

2. A method for treating hyperpiesia comprising administering to a patient in need of such treatment an effective amount of a pharmaceutical composition comprising an amount of a vasoactive intestinal polypeptide (VIP) analogue (SEQ ID NO: 2) selected from the group consisting of [L-Leu.sup.17]-VIP-Hse, [L-Leu.sup.17]-VIP-Hse-NH.sub.2, [L-Leu.sup.17]-VIP-Hse-NH(CH.sub.2).sub.9 CH.sub.3, [L-Leu.sup.17]-VIP-Hse-NH(CH.sub.2).sub.19 CH.sub.3 and a pharmaceutically acceptable salt thereof, effective to treat hyperpiesia, in combination with a surfactant and a pharmaceutically acceptable carrier.

3. A method for treating impotence comprising administering to a patient in need of such treatment an effective amount of a pharmaceutical composition comprising an amount of a vasoactive intestinal polypeptide (VIP) analogue (SEQ ID NO: 2) selected from the group consisting of [L-Leu.sup.17]-VIP-Hse, [L-Leu.sup.17]-VIP-Hse-NH.sub.2, [L-Leu.sup.17]-VIP-Hse-NH(CH.sub.2).sub.9 CH.sub.3, [L-Leu.sup.17]-VIP-Hse-NH(CH.sub.2).sub.19 CH.sub.3 and a pharmaceutically acceptable salt thereof, effective to treat impotence, in combination with a surfactant and a pharmaceutically acceptable carrier.

4. A method for treating anaphylaxis comprising administering to a patient in need of such treatment an effective amount of a pharmaceutical composition comprising an amount of a vasoactive intestinal polypeptide (VIP) analogue (SEQ ID NO: 2) selected from the group consisting of [L-Leu.sup.17]-VIP-Hse, [L-Leu.sup.17]-VIP-Hse-NH.sub.2, [L-Leu.sup.17]-VIP-Hse-NH(CH.sub.2).sub.9 CH.sub.3, [L-Leu.sup.17]-VIP-Hse-NH(CH.sub.2).sub.19 CH.sub.3 and a pharmaceutically acceptable salt thereof, effective to treat anaphylaxis, in

combination with a surfactant and a pharmaceutically acceptable carrier.

5. A pharmaceutical composition suitable for the treatment of asthma, hyperpiesia, impotence and accelerating secretions of the lachrymal gland, comprising an effective amount of a vasoactive intestinal polypeptide (VIP) analogue (SEQ ID NO: 2) selected from the group consisting of [L-Leu.^{sup.17}]-VIP-Hse, [L-Leu.^{sup.17}]-VIP-Hse-NH._{sub.2}, [L-Leu.^{sup.17}]-VIP-Hse-NH(CH._{sub.2})._{sub.9} CH._{sub.3}, [L-Leu.^{sup.17}]-VIP-Hse-NH(CH._{sub.2})._{sub.19} CH._{sub.3} and a pharmaceutically acceptable salt thereof, in combination with a surfactant and a pharmaceutically acceptable carrier.

6. A pharmaceutical composition according to claim 5, wherein said surfactant is selected from the group consisting of tannic acid or a salt thereof, saponin and a polyoxyethylene higher alcohol ether.

7. A pharmaceutical composition according to claim 5, further comprising a peptidase inhibitor.

8. A pharmaceutical composition according to claim 7, wherein said peptidase inhibitor is selected from the group consisting of trypsin inhibitor, chymotrypsin inhibitor, gavexate, guanidinobenzoic acid and an acidic polysaccharide.